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(54) **AUTOMATIC TOOL ORIENTATION CONTROL FOR BACKHOE WITH EXTENDABLE DIPPERSTICK**

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(58) **Field of Search** 37/347, 348, 907; 172/2, 3, 4, 4.5, 7, 9; 414/697, 699, 710; 701/50; 73/504.12, 504.13, 504.14

(56) **References Cited**

U.S. PATENT DOCUMENTS

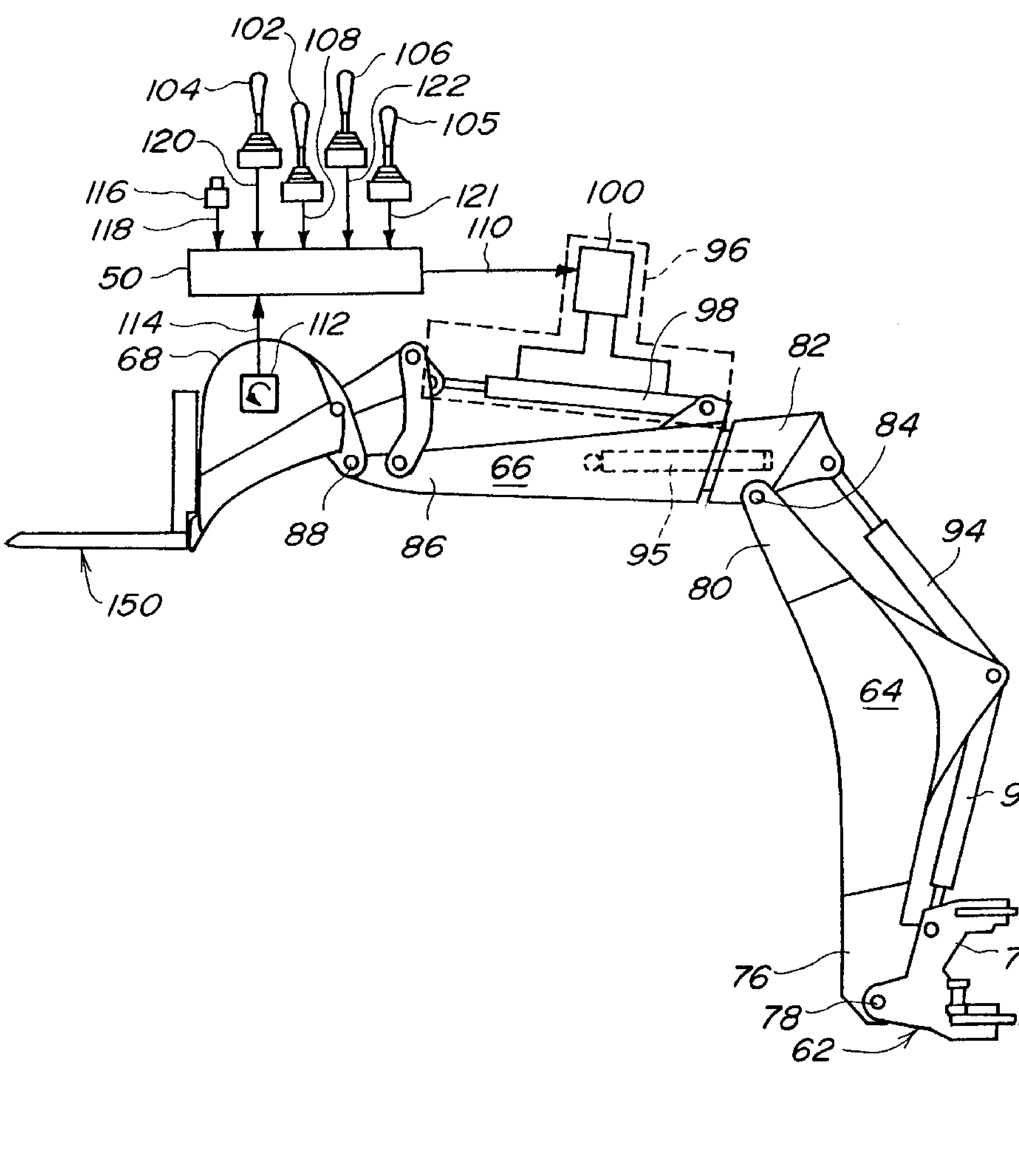
4,628,734	A	12/1986	Watson	73/505
4,844,685	A	7/1989	Sagaser	414/700
4,923,326	A	5/1990	Fietzke	403/371
5,356,260	A	10/1994	Ikari et al.	414/700
5,782,018	A	7/1998	Tozawa et al.	37/348
5,850,035	A	12/1998	Layton et al.	73/504.16
6,003,373	A	12/1999	Moore et al.	73/504.16
6,233,511	B1	5/2001	Berger et al.	701/50

Primary Examiner—Robert E. Pezzuto

(57) **ABSTRACT**

The invention comprises a backhoe with a tool pivotally attached to an extendable dipperstick, an actuator for controllably moving the tool about its pivot, and an angular velocity sensor for sensing the angular velocity of the tool about its pivot. A controller is adapted to perform a tool auto-hold function, automatically maintaining an initial tool orientation by processing the angular velocity data and commanding movement of the tool actuator to hold the angular velocity at zero. The controller is adapted to discontinue the tool auto-hold function when the operator manipulates a tool command input device affecting tool actuator movement, and resume the tool auto-hold function at the new orientation affected by the operator. Manipulation of an auto-hold command input device allows the operator to selectively enable and disable the tool auto-hold function.

5 Claims, 2 Drawing Sheets



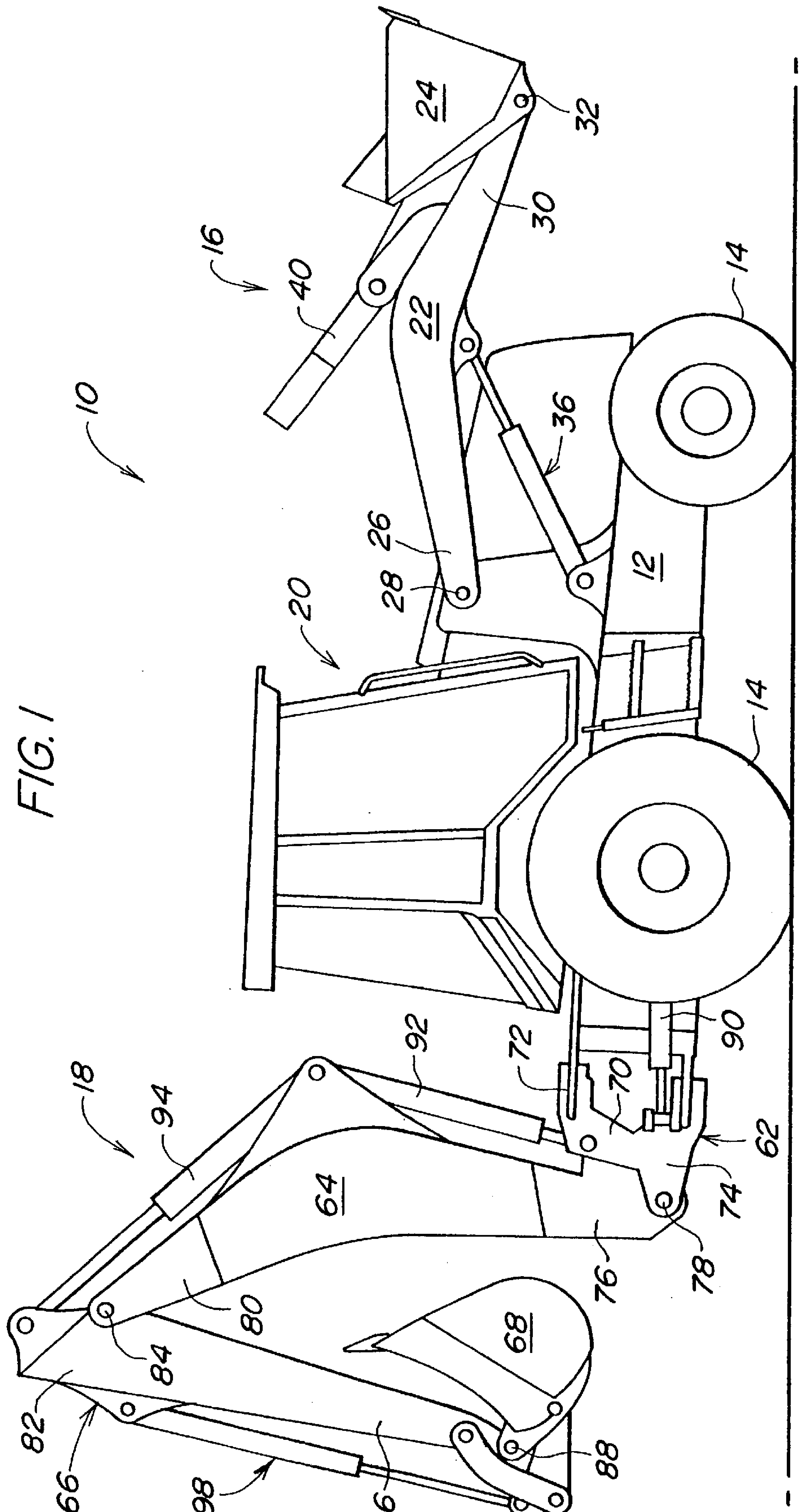

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FIG. 1

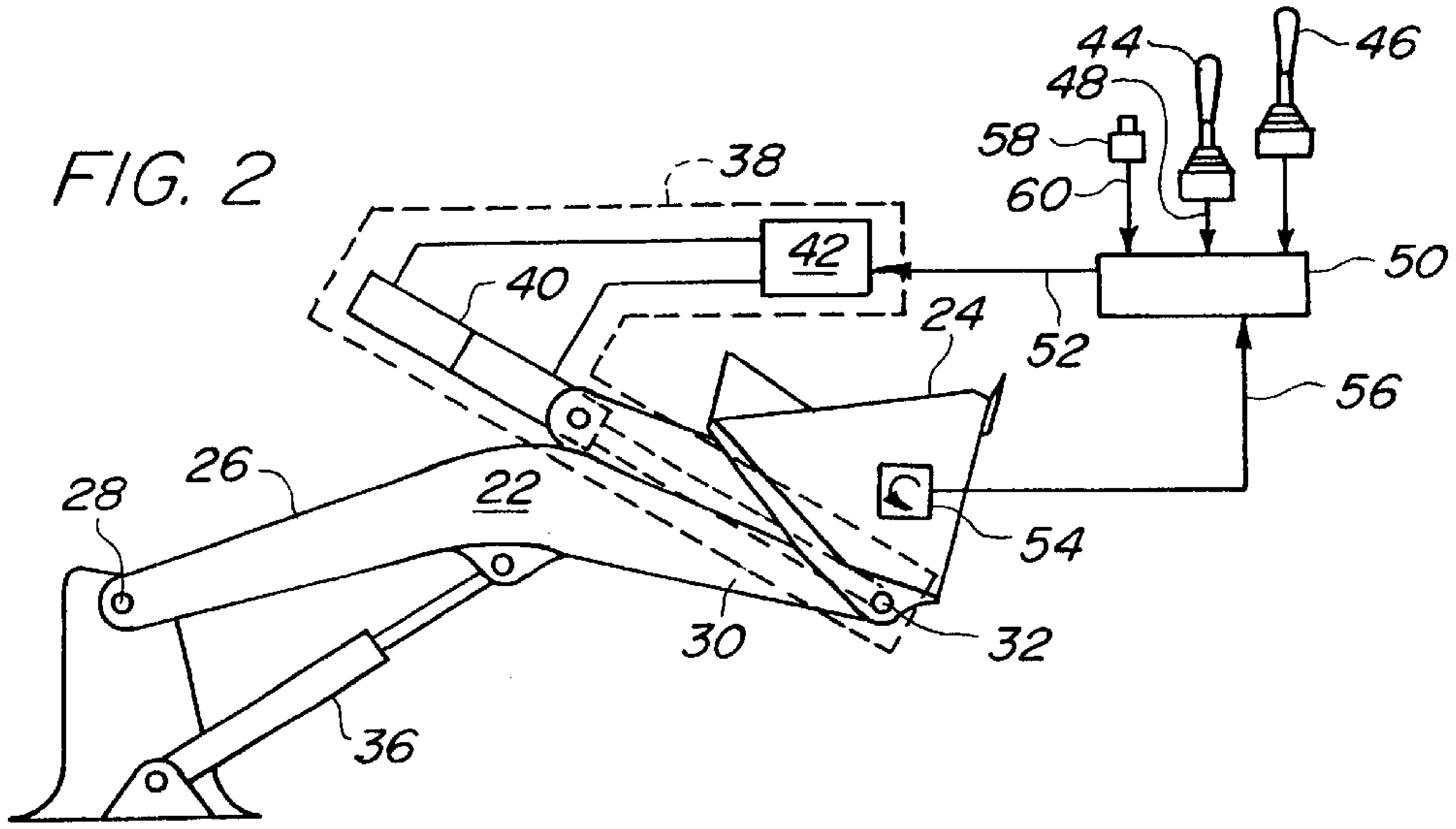
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FIG. 2

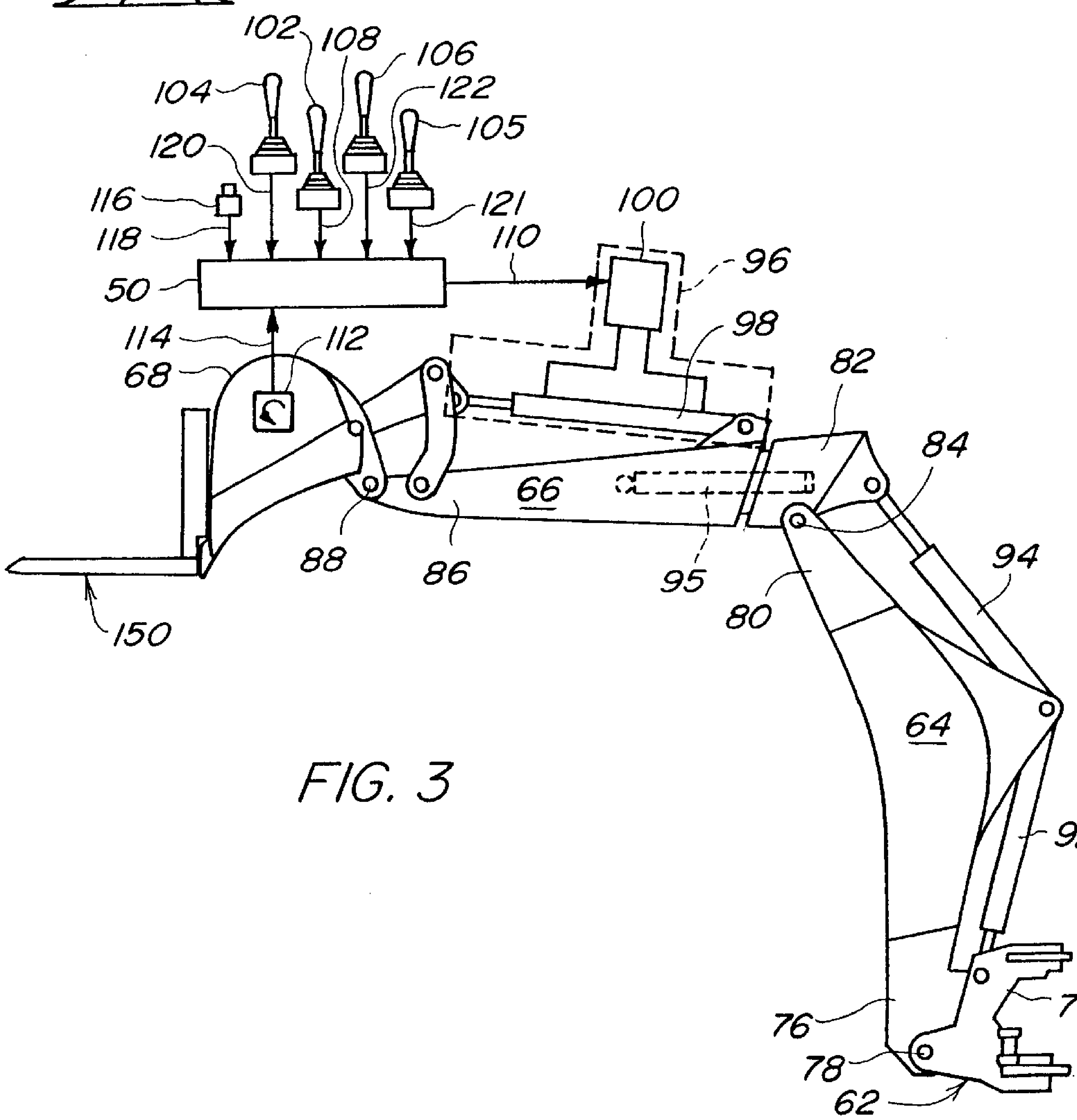
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FIG. 3

AUTOMATIC TOOL ORIENTATION CONTROL FOR BACKHOE WITH EXTENDABLE DIPPERSTICK

FIELD OF THE INVENTION

The present invention relates to a system for sensing and automatically controlling the orientation of a work tool pivotally attached to an extendable dipperstick of a backhoe, such as a backhoe bucket having telehandler tool features.

BACKGROUND OF THE INVENTION

A variety of work machines can be equipped with tools for performing a work function. Examples of such machines include a wide variety of loaders, excavators, telehandlers, and aerial lifts. A work vehicle such as a backhoe loader with an extendable dipperstick may be equipped with a tool, such as a backhoe bucket having telehandler tool features, for material handling functions. A swing frame pivotally attaches to the frame of the vehicle, a boom pivotally attaches to the swing frame, an extendable dipperstick pivotally attaches to the boom, and the tool pivotally attaches to the extendable dipperstick about a bucket pivot. A vehicle operator controls the orientation of the tool relative to the dipperstick by a tool actuator. The operator also controls the rotational position of the boom and dipperstick, as well as the translational extension of the dipperstick, by corresponding actuators. The aforementioned actuators are typically comprised of one or more double acting hydraulic cylinders and a corresponding hydraulic circuit.

During a work operation with a telehandler tool, such as lifting and moving baled material or palettes, it is desirable to maintain an initial tool orientation relative to gravity as the items are moved from one location to another. To maintain the initial tool orientation relative to gravity, where the tool is a backhoe bucket having telehandler tool features, the operator is required to continually manipulate a backhoe bucket command input device to adjust the tool as the backhoe boom and dipperstick are moved during the work operation. The continual adjustment of the tool orientation, combined with the simultaneous manipulation of a backhoe boom command input device, a dipperstick extension command input device, and a dipperstick command input device inherent in movement of the backhoe boom and dipperstick, requires a degree of operator attention and manual effort that diminishes overall work efficiency and increases operator fatigue.

A number of mechanism and systems have been used to automatically control the orientation of a tool such as a backhoe bucket. Various examples of electronic sensing and control systems are disclosed in U.S. Pat. Nos. 4,923,326, 4,844,685, 5,356,260, and 6,233,511. Control systems typical of the prior art utilize position sensors attached at various locations on the work vehicle to sense and control tool orientation relative to the vehicle frame.

A number of angular velocity sensors suitable for use in the present invention are commercially available. Examples of these types of angular velocity sensor are disclosed in U.S. Pat. Nos. 4,628,734, 5,850,035, 6,003,373. One example of such an angular velocity sensors is the BEI GYROCHIP® Model AQRS, marketed by the Systron Donner Internal Division of BEI Technologies of California.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved system for sensing and automatically controlling

the orientation of a tool pivotally attached to an extendable dipperstick of a backhoe or excavator.

The system automatically controls work tool orientation by making use of an angular velocity sensor attached to the tool to sense angular velocity of the tool about its pivot. The present invention comprises a backhoe, a swing frame pivotally attached to the frame of the backhoe, a boom pivotally attached to the swing frame, an extendable dipperstick pivotally attached to the boom, a tool pivotally attached to the extendable dipperstick, an actuator for controllably moving the tool about its pivot, and the aforementioned angular velocity sensor. A controller processes data from the angular velocity sensor and commands movement of the tool actuator in response. The preferred embodiment also includes a tool command input device to affect movement of tool actuator, and a tool auto-hold command input device to enable a tool auto-hold function for maintaining the tool in an initial orientation.

When the tool auto-hold function is enabled, the controller maintains the tool orientation by commanding the tool actuator to move the tool such that the angular velocity sensed about the tool pivot is zero. The controller is adapted to discontinue the tool auto-hold function when the operator manipulates the tool command input device to affect tool movement. The controller resumes tool auto-hold function once the operator discontinues manipulation of the tool command input device, reestablishing the initial tool orientation at the new orientation affected by the operator. Additionally, the operator may manipulate an auto-hold command input device to selectively enable and disable the tool auto-hold function.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of a backhoe loader.

FIG. **2** is a schematic diagram of a loader bucket orientation sensing and automatic control system.

FIG. **3** is a schematic diagram of a backhoe bucket orientation sensing and automatic control system for a backhoe with an extendable dipperstick.

DETAILED DESCRIPTION

FIG. **1** illustrates a self-propelled work vehicle, such as a backhoe loader **10**. A backhoe loader **10** has a frame **12**, to which are attached ground engaging wheels **14** for supporting and propelling the vehicle. Attached to the front of the vehicle is a loader assembly **16**, and attached to the rear of the vehicle is a backhoe assembly **18**. Both the loader assembly **16** and backhoe assembly **18** each perform a variety of excavating and material handling functions. An operator controls the functions of the vehicle from an operator's station **20**.

The loader assembly **16** comprises a loader boom **22** and a tool such as a loader bucket or other structure **24**. The loader boom **22** has a first end **26** pivotally attached to the frame **12** about a horizontal loader boom pivot **28**, and a second end **30** to which the loader bucket **24** pivotally attaches about a horizontal loader bucket pivot **32**.

A loader boom actuator, having a loader boom hydraulic cylinder **36** extending between the vehicle frame **12** and the loader boom **22**, controllably moves the loader boom **22** about the loader boom pivot **28**. A loader bucket actuator **38**, having a loader bucket hydraulic cylinder **40** extending between the loader boom **22** and the loader bucket **24**, controllably moves the loader bucket **24** about the loader bucket pivot **32**. In the illustrated embodiment, the loader bucket actuator **38** comprises a loader bucket electro-hydraulic circuit **42** hydraulically coupled to the loader bucket hydraulic cylinder **40**. The loader bucket electro-hydraulic circuit **42** supplies and controls the flow of hydraulic fluid to the loader bucket hydraulic cylinder **40**.

The operator commands movement of the loader assembly **16** by manipulating a loader bucket command input device **44** and a loader boom command input device **46**. The loader bucket command input device **44** is adapted to generate a loader bucket command signal **48** in response to manipulation by the operator, proportional to a desired loader bucket movement. A controller **50**, in communication with the loader bucket command input device **44** and loader bucket actuator **38**, receives the loader bucket command signal **48** and responds by generating a loader bucket control signal **52**, which is received by the loader bucket electro-hydraulic circuit **42**. The loader bucket electro-hydraulic circuit **42** responds to the loader bucket control signal **52** by directing hydraulic fluid to the loader bucket hydraulic cylinder **40**, causing the hydraulic cylinder **40** to move the loader bucket **24** accordingly.

During a work operation with the loader bucket **24**, such as lifting or transporting material, it is desirable to maintain an initial loader bucket orientation relative to gravity to prevent premature dumping of material. To maintain the initial loader bucket orientation as the loader boom **22** is moved relative to the frame **12** during a lifting operation, and as the vehicle frame **12** changes pitch when moving over uneven terrain during a transport operation, the operator is required to continually manipulate the loader bucket command input device **44** to adjust the loader bucket orientation. The continual adjustment of the loader bucket orientation requires a degree of operator attention and manual effort that diminishes overall work efficiency and increases operator fatigue.

FIG. **2** illustrates an improved actuator control system adapted to automatically maintain an initial loader bucket orientation. The present invention makes use of an angular velocity sensor **54** attached to the loader bucket **24**, in communication with the controller **50**. The loader bucket angular velocity sensor **54** is adapted to sense angular loader bucket velocity relative to the loader bucket pivot **32** and to continuously generate a corresponding angular velocity signal **56**. The controller **50** is adapted to receive the angular loader bucket velocity signal **56** and to generate a loader bucket control signal **52** in response, causing the loader bucket actuator **38** to move the loader bucket **24** to achieve a desired loader bucket angular velocity. Where the object of the invention is an auto-hold function to maintain the initial loader bucket orientation set by the operator, relative to gravity, the desired angular loader bucket velocity is zero. Additionally, the controller **50** is adapted to suspend the auto-hold function when the operator commands movement of the loader bucket **24** when receiving the loader bucket command signal **48**, and reestablishing the initial loader bucket orientation as the orientation of the loader bucket **24** immediately after the loader bucket command signal **48** terminates.

In applications requiring greater precision in maintaining the initial loader bucket orientation, the controller **50**, having computational and time keeping capabilities, is adapted to solve the integral for the loader bucket angular velocity as a function of time to determine deviation from the initial loader bucket orientation. The controller **50** is adapted to generate a loader bucket control signal **52** in response to deviation exceeding a desired loader bucket orientation deviation, causing the loader bucket actuator **38** to move the loader bucket **24** to achieve the desired loader bucket orientation deviation. Where the object of the invention is an auto-hold function to maintain the initial loader bucket orientation set by the operator, relative to gravity, the desired loader bucket orientation deviation is approximately zero. Additionally, the controller **50** is adapted to discontinue responding for the desired angular loader bucket velocity when responding for the desired loader bucket orientation deviation.

In the illustrated embodiment, the present invention also utilizes a loader auto-hold command switch **58** in communication with the controller **50**. The loader auto-hold command switch **58** is adapted to generate a loader auto-hold command signal **60** corresponding to a manipulation of the loader auto-hold command switch **58** by the operator to enable operation of the auto-hold function for the loader bucket **24**. The controller **50** is adapted to ignore the angular loader bucket velocity signal **56** unless receiving the loader auto-hold command signal **60** from the loader auto-hold command switch **58**.

The backhoe assembly **18** comprises a swing frame **62**, a backhoe boom **64**, an extendable dipperstick **66**, and a tool such as a backhoe bucket **68** having telehandler tool features. The swing frame **62** has a first end **70** pivotally attached to the frame **12** about a vertical pivot **72**, and a second end **74**. The backhoe boom **64** has a first end **76** pivotally attached to the second end **74** of the swing frame **62** about a horizontal backhoe boom pivot **78**, and a second end **80**. The extendable dipperstick **66** has a first end **82** pivotally attached to the second end **80** of the backhoe boom **64** about a horizontal dipperstick pivot **84**, and a second end **86** translationally extendable relative the first end **82**, to which the backhoe bucket **68** pivotally attaches about a horizontal backhoe bucket pivot **88**.

A swing frame actuator, having a swing frame hydraulic cylinder **90** extending between the vehicle frame **12** and the swing frame **62**, controllably moves the swing frame **62** about the vertical pivot **72**. A backhoe boom actuator, having a backhoe boom hydraulic cylinder **92** extending between the swing frame **62** and the backhoe boom **64**, controllably moves the backhoe boom **64** about the backhoe boom pivot **78**. A dipperstick actuator, having a dipperstick hydraulic cylinder **94** extending between the backhoe boom **64** and the dipperstick **66**, controllably moves the dipperstick **66** about the dipperstick pivot **84**. A dipperstick extension actuator, having a dipperstick extension hydraulic cylinder **95** extending between the first end **82** of the dipperstick and the second end **86** of the dipperstick, controllably extends the second end **86** of the dipperstick relative to the first end **82**. A backhoe bucket actuator **96**, having a backhoe bucket hydraulic cylinder **98** extending between the dipperstick **66** and the backhoe bucket **68**, controllably moves the backhoe bucket **68** about the backhoe bucket pivot **88**. In the illustrated embodiment, the backhoe bucket actuator **96** comprises a backhoe bucket electro-hydraulic circuit **100**, in connection the backhoe bucket hydraulic cylinder **98**, which supplies and controls the flow of hydraulic fluid to the backhoe bucket hydraulic cylinder **98**.

The operator commands movement of the backhoe assembly **18** by manipulating a backhoe bucket command input device **102**, a dipperstick command input device **104**, a dipperstick extension command input device **105**, a backhoe boom command input device **106**, and a swing frame command input device. The backhoe bucket command input device **102** is adapted to generate a backhoe bucket command signal **108** in response to manipulation by the operator, proportional to a desired backhoe bucket movement. The controller **50**, in communication with the backhoe bucket command input device **102**, dipperstick command input device **104**, dipperstick extension command input device **105**, backhoe boom command input device **106**, and backhoe bucket actuator **96**, receives the backhoe bucket command signal **108** and responds by generating a backhoe bucket control signal **110**, which is received by the backhoe bucket electro-hydraulic circuit **100**. The backhoe bucket electro-hydraulic circuit **100** responds to the backhoe bucket control signal **110** by directing hydraulic fluid to the backhoe bucket hydraulic cylinder **98**, causing the hydraulic cylinder **98** to move the backhoe bucket **68** accordingly.

During a telehandler work operation with a backhoe bucket **68** having telehandler tool features **150** for lifting and moving baled material or palettes, it is desirable to maintain an initial tool orientation relative to gravity as the items are moved from one location to another. To maintain the initial backhoe bucket orientation relative to gravity, the operator is required to continually manipulate the backhoe bucket command input device **102** to adjust the backhoe bucket orientation as the backhoe boom **64** and dipperstick **66** are moved during the work operation. The continual adjustment of the backhoe bucket orientation, combined with the simultaneous manipulation of the backhoe boom command input device **106**, the dipperstick extension command input device **105**, and the dipperstick command input device **104** inherent in movement of the backhoe boom **64** and dipperstick **66**, requires a degree of operator attention and manual effort that diminishes overall work efficiency and increases operator fatigue.

FIG. **3** illustrates an actuator control system adapted to automatically maintain an initial orientation backhoe bucket having telehandler tool features **150**. The present invention makes use of an angular velocity sensor **112** attached to the backhoe bucket **68**, in communication with the controller **50**. The backhoe bucket angular velocity sensor **112** is adapted to sense angular backhoe bucket velocity relative to the backhoe bucket pivot **88** and to continuously generate a corresponding angular velocity signal **114**. The controller **50** is adapted to receive the angular backhoe bucket velocity signal **114** and to generate a backhoe bucket control signal **110** in response, causing the backhoe bucket actuator **96** to move the backhoe bucket **68** to achieve a desired angular backhoe bucket velocity. Where the object of the invention is an auto-hold function to maintain the initial backhoe bucket orientation set by the operator, relative to gravity, the desired angular backhoe bucket velocity is zero. Additionally, the controller **50** suspends the auto-hold function while the operator commands movement of the backhoe bucket **68** when receiving the backhoe bucket command signal **108**, and reestablishes the initial backhoe bucket orientation as the orientation of the backhoe bucket **68** immediately after the backhoe bucket command signal **108** terminates.

The present invention also utilizes a backhoe auto-hold command switch **116** in communication with the controller **50**. The backhoe auto-hold command switch **116** is adapted to generate a backhoe auto-hold command signal **118** corresponding to a manipulation of the backhoe auto-hold command switch **116** by the operator to enable operation of the auto-hold function for the backhoe bucket **68**. The controller **50** is adapted to ignore the angular backhoe bucket velocity signal **114** unless receiving the backhoe auto-hold command signal **118** from the backhoe auto-hold command switch **116**.

Having described the illustrated embodiment, it will become apparent that various modifications can be made without departing from the scope of the invention as defined in the accompanying claims.

Assignment

The entire right, title and interest in and to this application and all subject matter disclosed and/or claimed therein, including any and all divisions, continuations, reissues, etc., thereof are, effective as of the date of execution of this application, assigned, transferred, sold and set over by the applicant(s) named herein to Deere & Company, a Delaware corporation having offices at Moline, Ill. 61265, U.S.A., together with all rights to file, and to claim priorities in connection with, corresponding patent applications in any and all foreign countries in the name of Deere & Company or otherwise.

What is claimed is:

1. A backhoe comprising:

a frame;

a boom having a first end and a second end, the first end being pivotally attached to the frame about a boom pivot;

an extendable dipperstick having a first end and a second end, the first end being pivotally attached to the second end of the boom about a dipperstick pivot, and the second end being translationally movable relative to the first end;

a tool being pivotally attached to the second end of the dipperstick about a tool pivot, the tool being adapted to perform a work function;

a tool actuator comprising a tool hydraulic cylinder and an electronically controlled tool hydraulic circuit, the tool hydraulic cylinder extending between the dipperstick and the tool, the tool actuator being adapted to controllably move the tool about the tool pivot in response to receiving a tool control signal;

a boom actuator comprising a boom hydraulic cylinder, the boom hydraulic cylinder extending between the frame and the boom, the boom actuator being adapted to controllably move the boom about the boom pivot;

a dipperstick actuator comprising a dipperstick hydraulic cylinder, the dipperstick hydraulic cylinder extending between the boom and the dipperstick, the dipperstick actuator being adapted to controllably move the dipperstick about the dipperstick pivot;

a dipperstick extension actuator comprising a dipperstick extension hydraulic cylinder, the dipperstick hydraulic cylinder extending between the first end and the second end of the extendable dipperstick, the dipperstick extension actuator being adapted to controllably translate the second end of the dipperstick;

a tool command input device being adapted to generate a tool command signal in response to manipulation by an operator corresponding to a desired tool movement;

an angular velocity sensor being attached to the tool, the angular velocity sensor being adapted to sense angular velocity of the tool about the tool pivot, and being adapted to continuously generate an angular velocity signal;

a controller having computational and time keeping capabilities, being in communication with the tool actuator, the tool command input device, and the angular velocity sensor, the controller being adapted generate a tool control signal to achieve the desired tool movement in response to receiving the tool command signal, the controller being further adapted to generate a tool control signal to continuously achieve a desired angular tool velocity in response to receiving the angular velocity signal when not receiving the tool command signal.

2. The backhoe as defined by claim 1 wherein the desired angular tool velocity is zero, resulting in maintenance of an initial tool orientation, and wherein the initial tool orientation is the orientation of the tool immediately after the tool command input device terminates generation of the tool command signal.

3. The backhoe as defined by claim 2 comprising a tool auto-hold command switch being in communication with the controller, the tool auto-hold command switch being adapted to generate a tool auto-hold command signal in response to manipulation by the operator, wherein the controller being adapted to ignore the angular velocity signal unless receiving the tool auto-hold command signal.

4. The backhoe as defined by claim 2 wherein the tool is a backhoe bucket having telehandler tool features.

5. The backhoe as defined by claim 1 wherein the tool is a backhoe bucket having telehandler tool features.

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